



BACKGROUND OF THE INVENTIONField of the Invention

The present invention relates to an information recording and/or reproducing apparatus to which a principle of scanning tunnel microscope is applied.

Related Background Art

Recent development is a scanning tunnel microscope as referred to as STM capable of directly observing an electron structure of surface atoms in a conductive material (G. Binnig et al. Phys. Rev. Lett., 49, 57 (1982)), allowing observation of real space image with an extremely high resolving power both for single crystal and for amorphous substance. The STM uses a tunnel current which flows if a probe and a conductive substance are brought close to each other at a distance of about 1 nm with a voltage therebetween. The electric current is so sensitive to a change of distance between them to exponentially change. Thus if the probe is scanned to keep the tunnel current constant, a surface structure of real space may be observed with a resolving power of order of atom. Although the analysis using the STM is limited to a conductive material, its applications cover structure analysis of thin insulating layer formed on a surface of conductive material. Further, since such apparatus and means use a method for detecting a micro electric current, the STM is advantageous to observe a medium without any damage and with a low power. Also, broad applications of STM are expected because of its operability in air.

Utilization of STM is active as a record reproduction apparatus of high density, for example as proposed in Japanese Patent Application Laid-Open Nos. 63-161552 and 63-161553. The apparatus uses a probe similar to that in the STM, in which an applied voltage is changed between the probe and a recording medium to record data on the recording medium. The recording medium is a material having a switching property with memorability in a voltage-current property, for example a thin film layer of a material selected from chalcogenides and  $\pi$ -electron organic compounds. The reproduction is based on a difference of tunnel resistance between a region thus recorded and a region not recorded. Also, the recording and reproduction is possible with a recording medium in which recording is achieved by changing a surface shape of recording medium by a voltage applied to the probe.

Another recording and reproducing apparatus is proposed in Japanese Patent Application Laid-Open No. 61-206148 using the STM, the semiconductor producing process techniques for formation

of probe, and the processing techniques for making a fine structure on a single substrate (K. E. Peterson, "Silicon as a Mechanical Material", Proceedings of the IEEE, Vol. 70, p.420, 1982). The apparatus is constituted such that a substrate is made of single crystal silicon, parallel springs are formed by fine processing to be finely movable in a direction parallel to a surface of substrate, i.e., in x, y-directions a tongue of cantilever beam with a probe formed thereon is provided on a moving part of the parallel spring, an electric field is applied between the tongue and a base, and the probe may be displaced by an electrostatic force in a direction perpendicular to the substrate surface, i.e. in the z-direction.

Similarly, Japanese Patent Application Laid-Open No. 62-281138 describes a recording apparatus provided with a converter array in which multiple tongues similar to that disclosed in the above 20 Japanese Patent Application Laid-Open No. 61-206148 are arranged.

A memory capacity of the above apparatus can be considered to increase by increasing an area of recording medium or by increasing the number of probe electrodes, to each of which an individual voltage may be applicable. In order to move the probe electrodes over a broad region along the surface of recording medium, an extremely high precision mechanism for coarse adjustment is required in addition to a mechanism for fine adjustment such as a cantilever, presenting a problem of scale increase of overall apparatus. While, if the number of probe electrodes to which respective voltages are independently applicable is simply increased to increase the memory capacity, wiring would be so complicated on the side of probe electrodes and the number of wire connections would become so huge. Especially, in case that a mechanism for fine adjustment is provided to independently displace the respective probe electrodes, wiring is necessary therefor. Thus it is uneasy to concentrate the entire wiring on the side of probe electrodes. It is, therefore, an object of the present invention to provide an apparatus which can perform recording and reproduction of high density and large capacity, simple in wiring and suitable for mass production, solving the above problems.

Further, there is such a problem in the conventional apparatus that if a transfer rate of transferring information to be recorded is faster than a write speed which is an addition of a write time of 1 bit by a probe electrode and an access time for movement of probe electrode to a desired recording area, the transferred information cannot be recorded on the recording medium due to mismatch caused between the information transfer rate and the write speed. This problem still exists in case of



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### DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. CL.5)
A	RESEARCH DISCLOSURE no. 186, October 1979, HAVANT GB pages 568 - 570 'Document storage on video disc' * page 570, left column, paragraph 3 - right column, paragraph 2; figure 6 *	6,7	
A	US-A-3 872 445 (PEASE) * column 7, line 17 - line 38; figure 2 *	6,7	
A	IBM TECHNICAL DISCLOSURE BULLETIN. vol. 24, no. 2, July 1981, ARMONK, N.Y., USA pages 1171 - 1172 P.J. KENNEDY 'Digital data storage using video disc' * the whole document *	6,7	
A	EP-A-0 381 113 (OLYMPUS OPTICAL CO., LTD.)		
A	US-A-3 710 352 (SMITH ET AL.)		TECHNICAL FIELDS SEARCHED (Int. CL.5)
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The present search report has been drawn up for all claims			
Place of search	Date of completion of the search	Examiner	
THE HAGUE	14 JUNE 1993	John D. FUX	
CATEGORY OF CITED DOCUMENTS		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application I : document cited for other reasons A : member of the same patent family, corresponding document	
X : particularly relevant if taken alone			
Y : particularly relevant if combined with another document of the same category			
A : technological background			
O : non-written disclosure			
P : intermediate document			



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**LACK OF UNITY OF INVENTION**

The Search Division considers that the present European patent application does not comply with the requirement of unity of invention and relates to several inventions or groups of inventions, namely:

1. Claims 1-5: Information recording or reproducing apparatus using a plurality electrically interconnected probe electrodes
2. Claims 6-8: Information recording or reproducing apparatus using a plurality of probe electrodes, a recording medium and a distinct temporary storage memory



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DOCUMENTS CONSIDERED TO BE RELEVANT			CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	
Y	FR-A-2 637 409 (OLYMPUS OPTICAL CO.) * page 4, line 27 - page 5, line 3 * * page 6, line 27 - page 9, line 27 * * page 11, line 31 - page 12, line 18 * * page 13, line 5 - page 14, line 5; claims 1-7; figures 1,5,6,8-10 * ---	1-5	G11B9/00 G11B11/00
Y	EP-A-0 397 416 (AMERSHAM INTERNATIONAL) * column 3, line 19 - line 32 * * column 7, line 14 - line 48 * * column 9, line 5 - line 27 * * column 9, line 51 - column 10, line 4; figures 3,4,8,9 *	1-5	
X	EP-A-0 382 192 (OLYMPUS OPTICAL CO., LTD.)	6	
A	* column 3, line 6 - line 33 * * column 4, line 18 - column 5, line 40 * * column 8, line 15 - line 29 * * column 8, line 40 - line 55; figures 1-4 *	1-5	
A	DE-A-3 823 010 (W. LEITZ GMBH) * column 2, line 25 - line 30 * * column 2, line 67 - column 5, line 3; figures 1,2 *	1,3,6	TECHNICAL FIELDS SEARCHED (Int. Cl.5)
A	DE-A-4 022 711 (OLYMPUS OPTICAL CO LTD) * column 14, line 29 - column 16, line 36 * * column 19, line 4 - line 26 * * column 21, line 11 - line 41; figures 14-17,26,27 *	1-6,8	G11B G11C G01N G01B
A	WO-A-8 907 256 (THE BOARD OF TRUSTEES OF THE LELAND STANFORD JUNIOR UNIVERSITY) * page 36, line 14 - line 20 * * page 36, line 35 - page 39, line 29; figures 39-41 *	1-6,8	
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The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
THE HAGUE		14 JUNE 1993	John D. FUX
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document			
T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same parent family, corresponding document			



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### CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing more than ten claims.

- All claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for all claims.
- Only part of the claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims and for those claims for which claims fees have been paid.  
namely claims:
- No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims.

### LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirement of unity of invention and relates to several inventions or groups of inventions.

namely:

See sheet -B-



All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.



Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid.

namely claims:



None of the further search fees has been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims.

namely claims:



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(54) Information recording and/or reproducing apparatus.

(57) The apparatus includes a recording medium (7-9,11,13) having a plurality of segmented planar electrodes (7-9), a plurality of probe electrodes (21-23) respectively facing the plural planar electrodes and electrically connected to each other, and a circuit (17) for independently applying a voltage for recording and/or reproducing between each pair of the planar electrodes and the probe electrodes. The information recording and/or reproducing apparatus

includes a circuit for inputting information to be recorded into the recording medium, a memory (19,20) other than the recording medium for temporarily storing the input information, and a circuit (16) for applying the recording voltages between a plurality of probe electrodes and segmented planar electrodes in correspondence with the information stored in the memory.

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FIG. 1

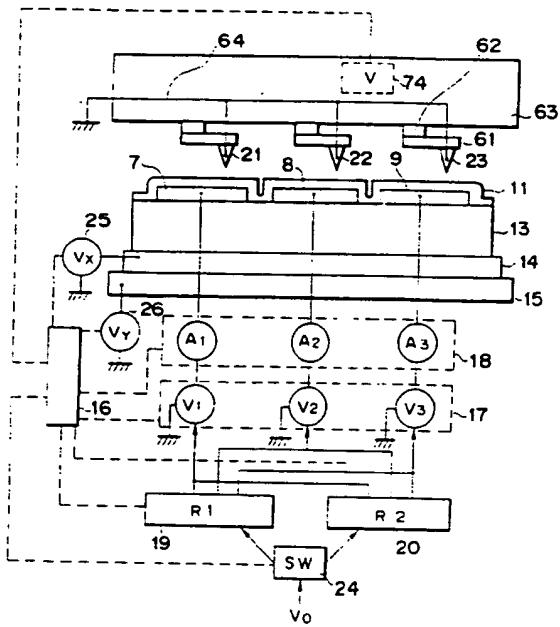


FIG. 7

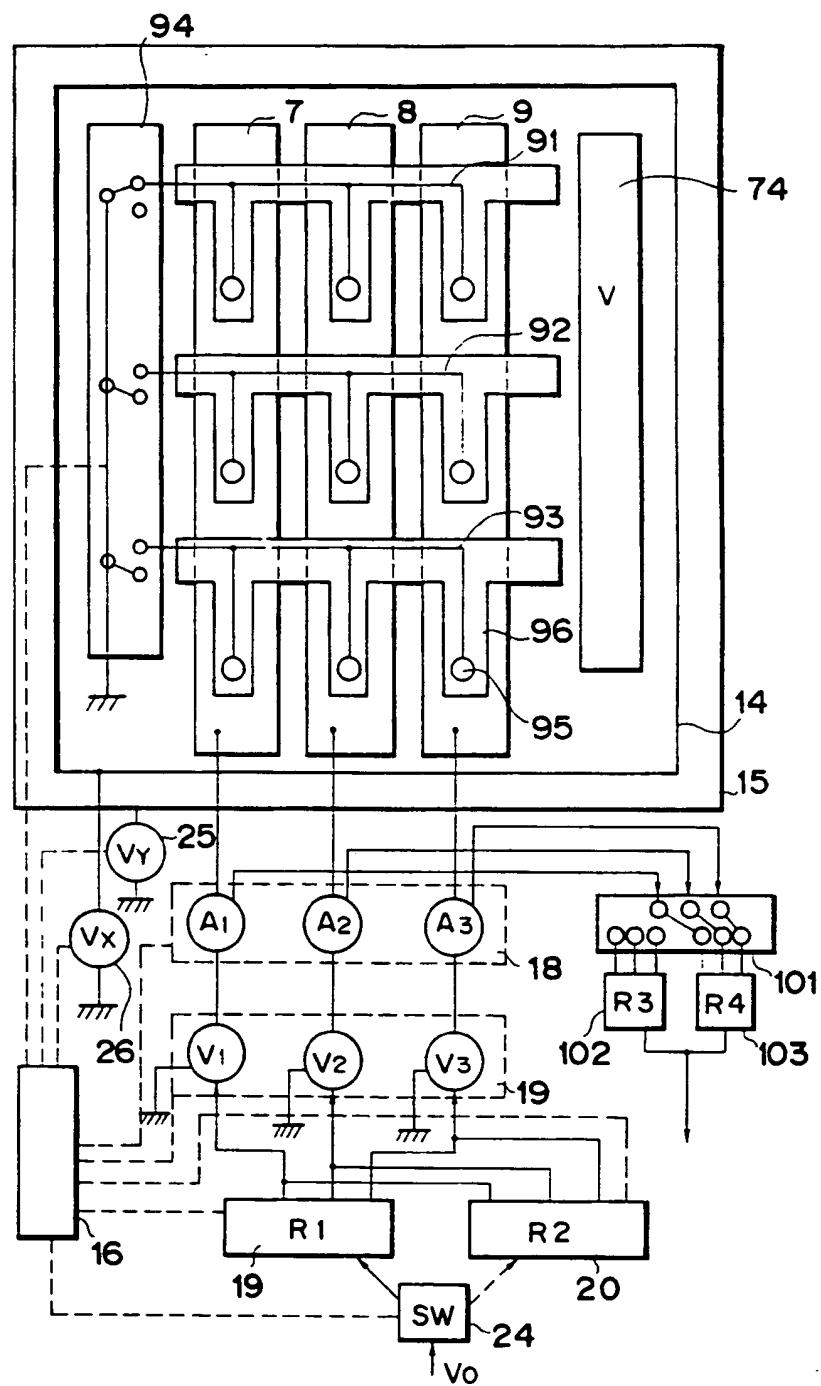


FIG. 8

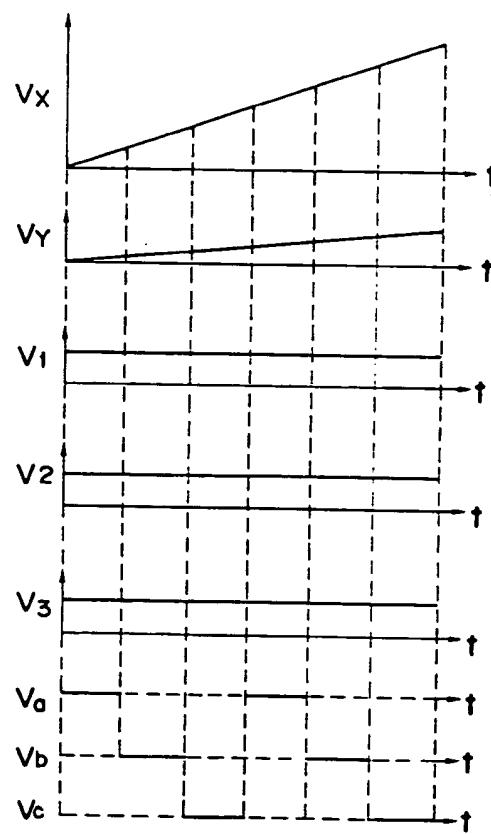


FIG. 5

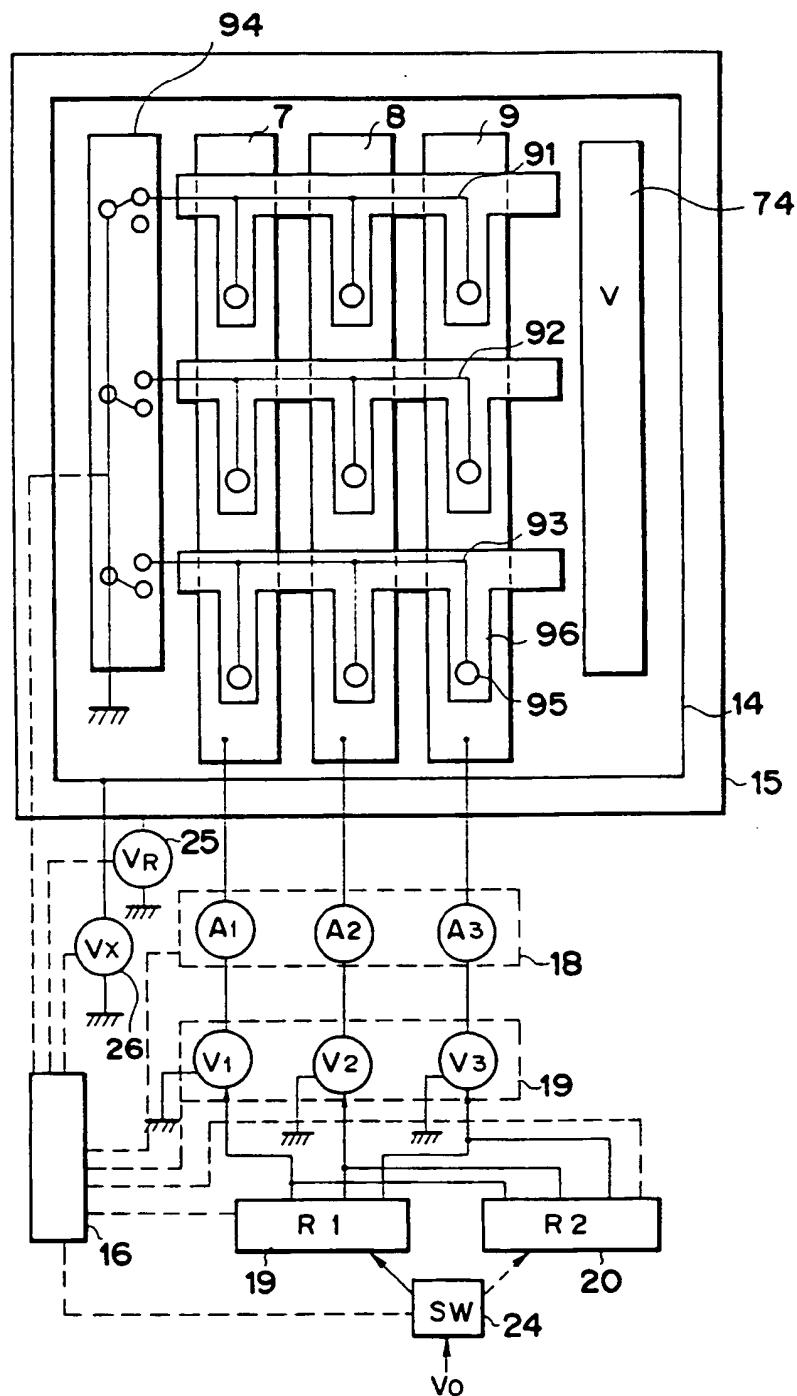


FIG. 6

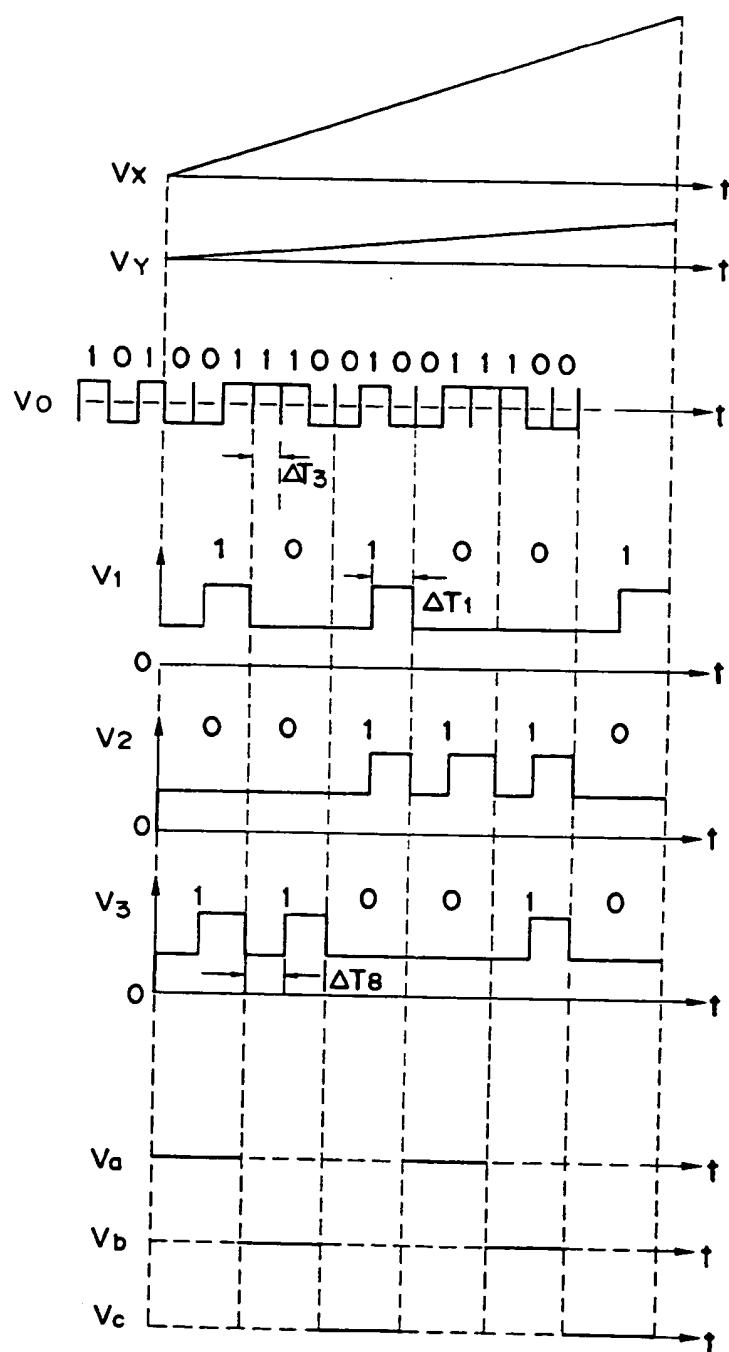


FIG. 1

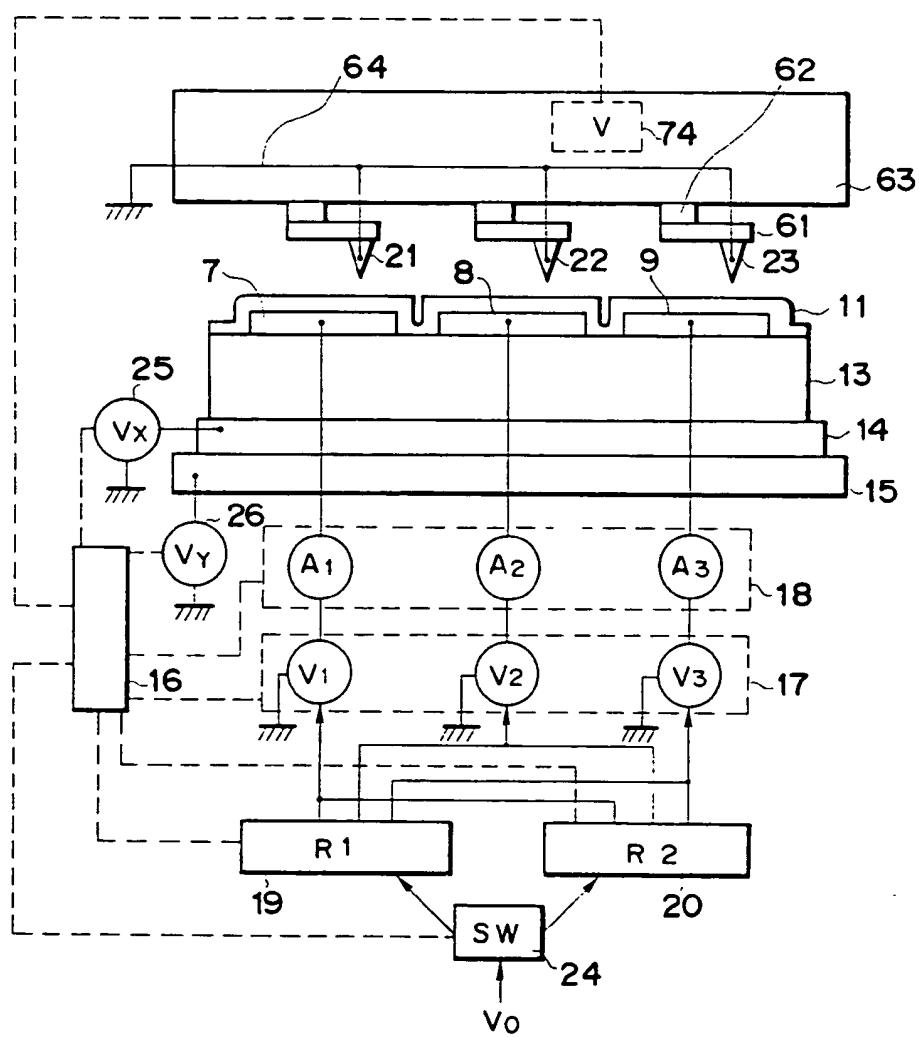
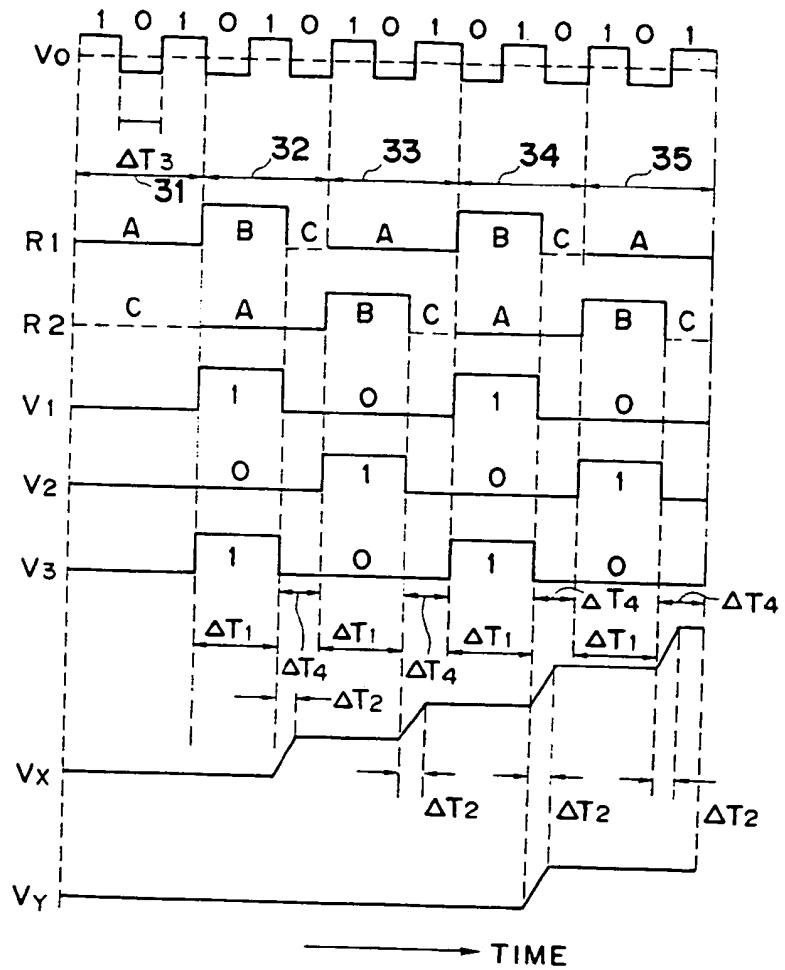


FIG. 2



A ; INPUT STATE  
 B ; OUTPUT STATE  
 C ; CLEAR STATE OR CEASE STATE

FIG. 3

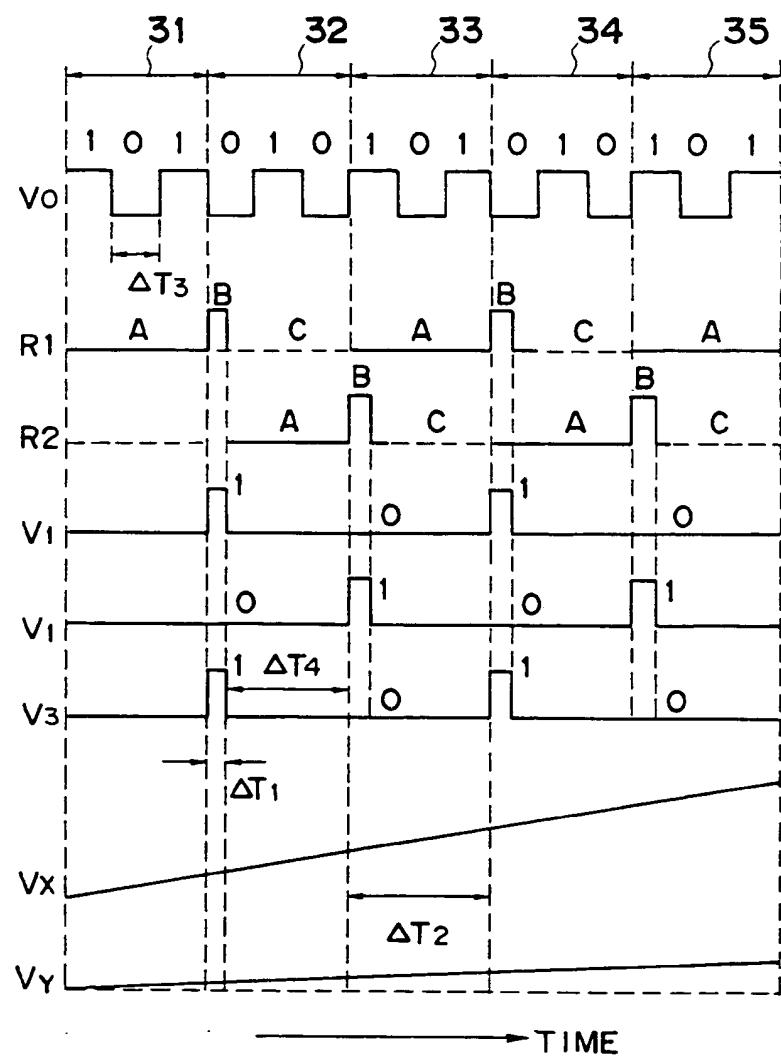
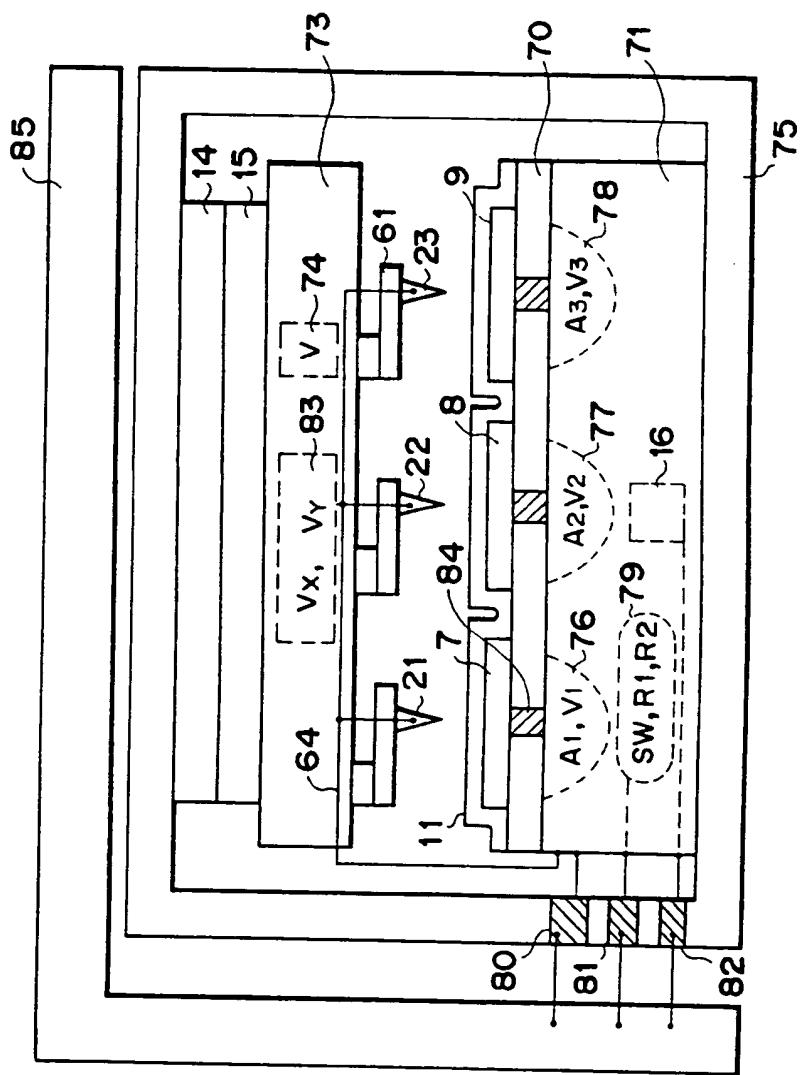


FIG. 4



and a probe electrode selected by a conductive line having a planar electrode and the plural probes, has a period  $\Delta T_3$  for controlling a distance between the recording medium surface and the probe electrode in a selection period, whereby providing a recording and/or reproducing apparatus of high density and large capacity with control of influence of cross talk in the non-write part.

Further, in the present embodiment, at least one group of probe electrodes face respective plural planar electrodes through the recording medium, and the write voltages are simultaneously applied for writing between the planar electrodes and the probe electrode group. The apparatus can perform high speed writing of information transferred thereto at a high speed onto the recording medium by sequentially repeating the writing operation for each of the probe electrode groups. The arrangement is of course unlimited by this. For example, a plurality of probe electrodes connected to mutually different conductive lines face the planar electrodes through the recording medium, and the write voltages may be applied between the mutually different conductive lines and the selected planar electrode while consecutively selecting the planar electrodes.

In Fig. 6, for example if an information signal  $V_0$  of information series of "101001110010011100" has been transmitted, the information transfer period  $\Delta T_3$  of 1 bit is shorter than the period  $\Delta T_1$  necessary for write of 1 bit by one probe electrode. It was conventionally impossible for one probe electrode to write the information series into the recording medium. In the present embodiment, the switching circuit 24 has a switching period of  $3\Delta T_3$ , one of two shift registers receives information of three digits out of the information series of  $V_0$  in the period of  $3\Delta T_3$ , the other register simultaneously outputs the information of three digits input to store in the preceding period of  $3\Delta T_3$  during the write period having  $3\Delta T_3$  to transmit the information of three digits to the three planar electrodes 7-9, the shift registers 19, 20 alternately repeat such operation, the scanner 94 consecutively selects the conductive lines 91-93 connected to the plural probes in synchronism with the operation, and the probe electrodes are relatively moved along the surface of recording medium by changing the voltages of  $V_x$ ,  $V_y$  during the operation, making the writing of large capacity and high speed real with simple wiring suitable for mass production.

Further, there are provided in the present embodiment at least two probe electrodes, preferably three, connected to one or plural conductive line(s), preferably three, so that nine probes may be effectively used by consecutively selecting the conductive lines in a chronological order to apply the write voltage between the planar electrode and the se-

lected conductive line.

#### Embodiment 6

Figs. 7 and 8 are drawings to illustrate an information reproducing apparatus of sixth embodiment of the present invention, Fig. 7 showing a structure of overall apparatus, and Fig. 8 a time chart upon drive. In Figs. 7 and 8,  $V_1$ ,  $V_2$ ,  $V_3$  represent bias voltages of read-out voltages normally of about 100 - 500 mV, which are applied to planar electrodes 7-9. While probe electrodes are moved along a surface of recording medium by changing voltages of  $V_x$ ,  $V_y$  for xy driving, a scanner 94 selectively scans conductive lines 91-93 to read out information written on the recording medium by electric current detecting means 18. Numeral 102 denotes a third shift register R3 and numeral 104 a fourth shift register R4, whereby read-out information is converted from parallel type information into serial type information. Alternate input and output of information by the shift registers reduces the number of information transmission lines. The read-out information by the electric current detecting means 18 is first stored in a memory area 11 other than the recording medium, and then the information is transferred outside, whereby matching information transmission. Upon selection, the read-out voltages are simultaneously applied for reading between the plural planar electrodes and the plural probe electrodes. In the present embodiment, there are provided a plurality of planar electrodes, the read-out voltages are applied between the probe electrodes and the planar electrodes, values of electric current flowing between the probe electrodes and planar electrodes are detected to detect displacement differences of probe position for read-out of information, enabling high speed reading.

Although the number of probe electrodes and the number of planar electrodes as shown in the above respective embodiments are several for simplification of explanation, a large number of electrodes, for example 2500, may be disposed in an actual arrangement to obtain a further effect.

According to the present invention, the recording and/or reproducing apparatus of high density and large capacity may be obtained in low cost, simple in wiring on the probe electrode side and suitable for mass production.

#### **Claims**

1. An information recording and/or reproducing apparatus comprising:  
a recording medium having a plurality of segmented planar electrodes;  
a plurality of probe electrodes respectively

- facing said plural planar electrodes and electrically connected to each other; and  
means for independently applying a voltage for recording and/or reproducing between each pair of the planar electrodes and the probe electrodes. 5
2. An information recording and/or reproducing apparatus according to Claim 1, further comprising means for adjusting a relative positional relation between said recording medium and the respective probe electrodes. 10
3. An information recording and/or reproducing apparatus according to Claim 2, further comprising means for conducting the recording and/or reproducing while moving said probe electrodes along a surface of recording medium. 15
4. An information recording and/or reproducing apparatus according to Claim 2, further comprising means for independently displacing said plural probe electrodes. 20
5. An information recording and/or reproducing apparatus according to Claim 4, wherein said displacing means has displaceable beams to support the probe electrodes. 25
6. An information recording and/or reproducing apparatus, comprising:  
means for inputting information to be recorded into a recording medium;  
a memory other than said recording medium for temporarily storing said input information; and  
means for applying recording voltages between a plurality of probe electrodes and segmented planar electrodes in correspondence with the information stored in said memory. 30  
35
7. An information recording and/or reproducing apparatus according to Claim 6, wherein said memory comprises first and second shift registers to convert inputting serial information into parallel information, said first and second shift registers alternately conducting input and output of information. 40  
45
8. An information recording and/or reproducing apparatus according to Claim 6, further comprising a package in which said recording medium and probe electrodes are sealed in unity. 50  
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recording medium, the voltages are applied, which allows effective application of voltage at the recording position and discrete formation of record bits to advantageously make the judgement of record bits easy.

Specifically, the write of information is conducted as follows. The switching circuit 24 selects either of the first shift register 19 and the second shift register 20 respectively having the same number of memories as the number of plural probe electrodes to consecutively transfer serial information. The storage of information is stopped when one of the shift registers becomes full with storage of information corresponding to the number of probes. The write voltages corresponding to the stored information in the shift register are respectively applied between the planar electrodes and the probe electrodes. The batch write of information is executed in parallel on the plural recording parts made access to by the plural probe electrodes. After completion of write, the probe electrodes are again moved to another desired region on the recording medium. Next information is transmitted to the other shift register in the same manner as above during the previous write in the one shift register, during the movement of probe electrodes, or in the clear state "C" of the shift register which has just output the write voltages, preparing the next batched writing. The alternative operations are repeated. For example, the information transfer period  $\Delta T_3$  of 1 bit out of the information signal  $V_0$  having serial information of 101010.... is shorter than the time  $\Delta T_1$  necessary for one probe electrode to write 1 bit, so that it was impossible in the conventional arrangements for one probe electrode to write the above information series on the recording medium 11. Even if a plurality of probe electrodes are used, the writing of the above information series was unreal due to mismatch between the information transfer rate and the write speed. In contrast in the present embodiment, while the switching circuit 24 has the switching period of  $3\Delta T_3$  and one of the paired shift registers receives information of three digits out of the information series of  $V_0$  in the period of  $3\Delta T_3$ , the other shift register simultaneously outputs information of three digits input to store during the preceding  $3\Delta T_3$  period to the three planar electrodes during the write period of  $2\Delta T_3$  ( $= \Delta T_1$ ). Alternately repeating this operation by the two shift registers while matching the information transfer rate with the write speed, the writing of the above information series is carried out into the record medium 11.

More specifically, the shift register 19 is in the input state "A" in a section 31 to receive an information series of three digits "101". The shift register 19 becomes into the output state "B" in a next section 32 to control the write voltages of  $V_1$ ,

$V_2$ , and  $V_3$  as "1", "0", and "1" based on the information series received in the preceding section 31. Then the shift register 19 becomes into the clear state or cease state for adjustment "C", and the shift register 20 becomes into the input state to receive a next information series of "010". Similarly in a next section 33, the shift register 20 first becomes into the output state to control  $V_1$ ,  $V_2$ ,  $V_3$  as "0", "1", "0" based on the information series received in the preceding section 32. The shift register 20 then becomes into the state "C", and the shift register 19 becomes into the input state to receive a following information series of "101". There are similarly executed in following sections 33 - 35 the split and distribution of information series into the shift registers, the alternate input and output of the shift registers, and the control of write voltages of  $V_1$ ,  $V_2$ ,  $V_3$ , enabling the matching between the information transfer rate and the write speed in the present embodiment.

## Embodiment 2

Next explained is a second embodiment according to the present invention. An arrangement of apparatus is the same as in Fig. 1. Fig. 3 is a drawing to show a time chart of drive in the second embodiment according to the present invention. The present embodiment is featured by batched writing with continuous movement of plural probe electrodes 21-23 along the surface of recording medium 11. The others except this feature are the same as in the first embodiment.

In the present embodiment, the probe moving period  $\Delta T_2$ , which is a time period necessary for movement of probe electrodes by a distance necessary for recognition of 1 bit, is longer than the information transfer period of 1 bit of information signal voltage  $V_0$ . In such case, the conventional arrangements did not allow writing of information series of the above information signal voltage onto the recording medium 11 even with plural probe electrodes. Further, the period  $\Delta T_1$  necessary for write is shorter than  $\Delta T_3$ . In case that  $\Delta T_1 > \Delta T_3$ , the writing of information series was conventionally unable, either.

In the present embodiment, the batch writing is carried out by alternately repeating the input and output of shift registers 19, 20 while continuously changing values of  $V_x$ ,  $V_y$  as shown in the time chart of Fig. 3 to two-dimensionally scan to move the surface of recording medium 11 relative to the probe electrodes. This enables the writing onto the record medium 11 even when the information series is transferred in the information transfer period for 1 bit shorter than the moving period  $\Delta T_2$  of probe electrodes necessary for recognition of 1 bit.

Embodiment 3

Next explained with reference to Fig. 4 is a third embodiment according to the present invention. In the present embodiment, planar electrodes are positioned on a semiconductor substrate and an integrated circuit is formed on the side of planar electrodes. The present embodiment prevents concentration of complicated peripheral circuits and wiring lines on the probe electrode side due to the increase in number of probes. Also, the present embodiment has high general-purpose properties in that a closed unit containing the recording medium and other members is detachably mounted.

In Fig. 4, numerals 76-78 are either of voltage applying circuit, electric current detecting circuit, or the both. The voltage applying circuit and the current detecting circuit for respective planar electrodes are formed on a semiconductor substrate 71, on which the planar electrodes are placed. This arrangement achieved simplification of overall apparatus without necessity of complicated wire connections as compared to the conventional arrangements. Further, numeral 70 is an insulating layer for insulating the planar electrodes to electric circuits on the semiconductor substrate, and numeral 84 a through hole electrode for connecting the planar electrodes and the electric circuits on the semiconductor substrate 71. A section 79 has functions of switching circuit and shift register, so that the switching circuit for splitting to distribute information and shift registers are formed on the semiconductor substrate 71. Further, a micro computer 16 is formed on the semiconductor substrate 71. Numeral 83 denotes an xy scan drive circuit formed on the silicon substrate on the side where the probe electrodes are formed, to drive respective scan mechanisms 14, 15. Numeral 85 designates a main body of recording and/or reproducing apparatus on which a closed package 75 with the connection terminals is freely mountable, numeral 80 a connection terminal for power supply, numeral 81 a terminal for information transmission, and 82 a terminal for micro computer control.

The recording and/or reproducing apparatus of the present embodiment is featured by detachable arrangement of unit in which the probe electrodes, the recording medium, and the segmented planar electrodes are packed together in unity in the closed package 75 with the connection terminals 80-82. The recording and/or reproducing apparatus of the present embodiment is suitable for mass production with high reliability by packaging the complicated peripheral circuits together in a cassette.

Embodiment 4

Next explained is a fourth embodiment according to the present invention. Fig. 5 is a drawing to show a structure of the fourth embodiment. The fourth embodiment is the same as the first embodiment except that a plurality of conductive lines connected to a plurality of probe electrodes are provided.

There are provided in the present embodiment a plurality of conductive lines 91-93 connected to a plurality of parallel segmented electrodes 7-9 and a plurality of probe electrodes 95. Since the plural probe electrodes face mutually different planar electrodes 7-9, which are independently controllable, with a recording medium inbetween which is omitted in Fig. 5, information of write may be transferred in parallel through the planar electrodes 7-9 while sequentially selecting to scan the conductive lines 91-93 having the plural probe electrodes. It is also possible to transfer the write information in parallel through the plural conductive lines 91-93 while sequentially selecting to scan the planar electrodes 7-9, because the planar electrodes face the plural probe electrodes connected to mutually different conductive lines with the recording medium inbetween. The present embodiment has the former arrangement of peripheral circuits. Numeral 94 designates a selection circuit for sequentially selecting the conductive lines 91-93 having the plural probe electrodes one by one in a chronological order, and 96 bimorph beams arranged in a matrix.

In the present embodiment, each of the plural parallel planar electrodes is an electrode of band shape, which is advantageous in that the wiring may be simplified. Especially, the wiring arrangement may be extremely simplified because the conductive lines 91-93 have the plural probes aligned in respective rows relative to each other and facing the respective planar electrodes different from each other, and the rows of plural probes and the columns of band planar electrodes are positioned in a skew relation through the recording medium, forming a matrix arrangement.

Embodiment 5

Fig. 6 is a drawing to illustrate a fifth embodiment according to the present invention, which is a time chart of drive of recording and/or reproducing apparatus structured in the same manner as the fourth embodiment. In Fig. 6,  $V_a$ ,  $V_b$ ,  $V_c$  represent states of voltage of conductive lines 91-93 connected to plural probes, and line selection states of scanner 94, in which a solid line shows a setting voltage with presence of selection, and a dotted line shows a disconnect state of non-selected state.

A probe electrode in non-selected state is held in a condition separated from a recording medium,

plural probe electrodes provided in that mismatch is caused between the information transfer rate and the write speed though the write speed may be increased within a limited time. It is a further object of the present invention to provide an apparatus with use of plural probe electrodes which allows high speed writing with match between the information transfer rate and the writing speed.

#### SUMMARY OF THE INVENTION

An information recording and/or reproducing apparatus according to the present invention, which solved the above problems, comprises a recording medium having a plurality of segmented electrodes, a plurality of probe electrodes respectively facing the plural planar electrodes and electrically connected to each other, and means for independently apply a voltage for recording and/or reproducing between each pair of the planar electrodes and the probe electrodes.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a drawing to show a whole structure of first embodiment according to the present invention;

Fig. 2 is a drawing to show a time chart of first embodiment;

Fig. 3 is a drawing to show a time chart of second embodiment;

Fig. 4 is a drawing to show a whole structure of third embodiment;

Fig. 5 is a drawing to show a whole structure of fourth embodiment;

Fig. 6 is a drawing to show a time chart of fifth embodiment;

Fig. 7 is a drawing to show a whole structure of sixth embodiment; and

Fig. 8 is a drawing to show a time chart of sixth embodiment.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

##### Embodiment 1

Fig. 1 is a drawing to show a structure of first embodiment of recording and/or reproducing apparatus according to the present invention. In Fig. 1, numerals 21-23 are probe electrodes, each of which may be displaced in a direction perpendicular to a surface of recording layer for adjustment of distance between the probe electrode and the recording layer. There is a bimorph beam 61 provided as means for adjusting the distance between each of the probe electrodes and the recording medium. Numeral 62 denotes a base for the

bimorph beam 61, and a plurality of bimorph beams or cantilever beams are formed on a single silicon substrate 63. Numeral 74 designates a drive circuit for driving to independently displace each of bimorph beams, which is formed on the same substrate as the silicon substrate 63 by using a semiconductor process. Wiring of independent conductive lines is provided on the silicon substrate 63 to connect each of the bimorph beams to the drive circuit 74, though not shown in Fig. 1. Numeral 64 denotes a conductive line which electrically connects all the probe electrodes 21-23 and is led outside to be earthed. The above arrangement constitutes a probe electrode unit.

Further, the following arrangement is provided on the recording medium side to face the probe electrode unit. Numerals 7-9 are a plurality of segmented planar electrodes which are disposed on a single substrate 13 to face the respective probe electrodes 21-23. Numeral 11 denotes a recording layer in which information is recorded by switching change of conductivity (current-voltage property) of recorded part, covering over all the planar electrodes 7-9. The recording medium is constituted by the substrate 13, the planar electrodes 7-9, and the recording layer 11. In the present embodiment, a polyimide thin film made by the Langmuir-Blodgett technique is used as the recording layer 11 of the recording medium. The recording medium, however, is not limited to that, and other media may be employed such as those disclosed in Japanese Patent Application Laid-Open Nos. 63-161552 and 63-161553. Although one of features of the present invention is use of recording medium having the plurally segmented electrodes, its arrangement is not limited to that in which the recording layer is formed on the planar electrode, and such an arrangement may be employed that the recording layer itself has a function of electrode. In the alternative arrangement, the recording medium may be structured by arrangement of plural blocks of segmented recording layer having the function of electrode, which are separated from each other to avoid a contact.

Numeral 16 designates a micro computer for write and read of information to totally control the entire apparatus. Numerals 14, 15 are moving means for relatively moving the probe electrodes 21-23 in the x, y-directions along the surface of recording layer 11, numeral 14 is an x scan mechanism for moving the probe electrodes 21-23 in the x-direction, and 15 is a y scan mechanism for moving them in the y-direction.

Numeral 25 is a drive circuit of the x scan mechanism 14, and  $V_x$  represents a drive voltage. Further, numeral 26 is a drive circuit of y scan mechanism 15, and  $V_y$  represents a drive voltage thereof. Numeral 17 designates a voltage applying

circuit, which applies either a predetermined pulse voltage for write or a predetermined bias voltage for read respectively independently to each set of the planar electrodes 7-9 and the counter probe electrodes 21-23.  $V_1$ ,  $V_2$ , and  $V_3$  represent values of voltage applied to respective pairs of probe electrodes 21-23 and planar electrodes 7-9. Numeral 18 is a current detecting circuit for detecting values of electric current flowing between each pair of probe electrodes and planar electrodes.  $A_1$ ,  $A_2$ , and  $A_3$  represent values of electric current respectively flowing between respective pairs of probe electrodes 21-23 and the planar electrodes 7-9. Data recorded on the medium at a position of probe may be reproduced by reading a value of electric current flowing through the electric current detecting circuit 18 when the bias voltage for read is applied by the voltage applying circuit 17.

In the present embodiment, since the voltage applying circuit 17 and the electric current detecting circuit 18 are connected on the side of planar electrodes, an enough room is created in a mounting density of silicon substrate 63 on the probe electrode side as compared to the conventional apparatus. Further, since the probe electrodes 21-23 are connected by the single common conductive line 64, the wiring on the silicon substrate on the probe electrode side may be advantageously simplified. Especially in the arrangement of the present embodiment using the means (bimorph beam) for independently moving the respective probe electrodes, a number of conductive lines must be wired on the same silicon substrate 63 to connect the respective bimorph beams and the drive circuit, so that the single line connection of probe electrodes is extremely advantageous by reduction in the number of wiring lines.

$V_0$  represents a voltage of information signal to be recorded, and numerals 19, 20 designate a first shift register R1 and a second shift register R2 respectively having the same number of memory segments as the number of plural probe electrodes. Numeral 24 denotes a switching circuit, which splits to distribute the information signal  $V_0$  serially input thereto to the shift registers 19 and 20. The information signal voltage  $V_0$  is temporarily stored in either of the shift registers 19, 20 through switching circuit 24. During storage into a shift register, write of information is carried out in parallel on the recording layer 11 by applying the pulse write voltage between the probe electrodes 21-23 and the planar electrodes 7-9 in correspondence with the information having already stored in the other shift register. Thus the first shift register 19 and the second shift register 20 are provided to convert the transfer information from the serial type into the parallel type. The batched writing may be conducted in parallel by smoothly converting the

serial type information advantageous in transmission of information with less information lines by alternate input and output of information through the first and second shift registers. Further, since the write voltage is simultaneously applied between the plural planar electrodes 7-9 and the plural probe electrodes 21-23, a fine error in set position of probe electrodes relative to the recording medium, which is caused by a temperature drift with time, may be approximately equalized among the probes, assuring stable reliability among the probes.

Fig. 2 shows a time chart of drive of apparatus in the present embodiment, in which an axis of abscissa is a time, and "1" and "0" are values of information. R1 and R2 show operational states of the first shift register 19 and the second shift register 20, respectively. A represents an input state of information, B an output state of information, and C a clear state of information or a cease state for adjustment. Further,  $\Delta T_1$  represents an application period of write voltage or a write period, and  $\Delta T_4$  a non-write period. The voltages of  $V_1$  -  $V_3$  include two kinds of write voltage corresponding to the state "1" and the state "0" in the write period  $\Delta T_1$ , and a bias voltage normally of about 100 - 500 mV in the other period. Here, the write voltage corresponding to the state "0" is set to the same value as the bias voltage.  $\Delta T_2$  is a period for relatively moving the probe electrodes 21-23 along the surface of recording medium 11 by changing the voltage value of ( $V_x$ ,  $V_y$ ), and  $\Delta T_3$  an information transfer time of 1 bit. The information transfer rate may be represented by  $1/\Delta T_3$ . In Fig. 2, numerals 31-35 denote switching periods of shift registers 19, 20 by the switching circuit 24. In the present embodiment, matching is obtained between the information transfer rate ( $1/\Delta T_3$ ) and the writing rate ( $1/(\Delta T_1 + \Delta T_2)$ ) such that the first shift register 19 and the second shift register 20 are provided with the same number of memories as the number of plural probe electrodes, that the input and output of information are carried out in the switching periods 31 - 35 by the first shift register 19 and the second shift register 20, and that the paired shift registers respectively having three memories for the three probe electrodes are equipped to alternately conduct the input and output.

In the present embodiment, the voltages  $V_1$  -  $V_3$  applied between the plural probe electrodes 21-23 and the segmented electrodes 7-9 have the write period  $\Delta T_1$ , in which the write voltage is applied and the non-write period  $\Delta T_4$ , the plural probe electrodes 21-23 are moved in a period  $\Delta T_2$  within the non-write period  $\Delta T_4$  along the surface of the recording medium 11. After the probe electrodes have made access to a recording position on the